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EMISSION CHARACTERISTICS OF CRUDE OIL PRODUCTION OPERATIONS IN CALIFORNIA

EXECUTIVE SUMMARY

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SUMM

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ABSTRACT

An inventory was conducted of the average annual emissions of air pollutants; NO_x, SO_x, CO, particulate matter and hydrocarbons; from oil production operations in the state of California. The emissions were generated on a lease-by-lease basis and aggregated and reported by (1) oil field (with associated geographical location), (2) County, and (3) Air Basin. Preparation of this emission inventory involved field surveys of representative production sites for equipment inventorying; field tests of oil field IC engines and heaters for emission factor development; and processing of extensive data from the California Division of Oil and Gas, the American Petroleum Institute, and other sources for emissions calculation.

On the basis of this program it was concluded that the emissions from oil production in California are a significant portion of the total emissions from stationary sources. In the South Coast Air Basin alone, oil production accounted for 18 percent of the CO, over 3 percent of the NO_x, 2 percent of the SO_x, over 3 percent of the hydrocarbons and less than 1 percent of the particulate stationary sources emissions during the 1979 study year.

CONTENTS

TABLES

SECTION 1.0

BACKGROUND

Crude oil production in California is a significant air pollution emission source. A 1976 inventory conducted by KVB showed 5 percent of the total hydrocarbon emissions in the South Coast Air Basin resulted from crude oil production. In addition to these fugitive hydrocarbons, the engines, heaters, steamers and fireflooding operations in the oil fields produce considerable quantities of nitrogen oxides, sulfur oxides and fine particulate matter.

There were approximately 230 active oil fields and over 43,000 oil wells in California when this program began in 1979, some located in very remote locations. While the California Division of Oil and Gas (DOG) regulates the various oil production operations and maintains location and production data for each well, there was very little information available concerning the type or quantity of equipment located at each site. There are many oil production companies ranging in size from the "major" oil companies to small independent producers who may own only one oil well. In addition, there are many small independent companies who specialize in well drilling, remedial work and welding services as subcontractors to these oil production companies.

The ARB in their continuing effort to upgrade the statewide emissions inventory and provide assistance to the local air pollution control agencies engaged KVB in 1979 to inventory the emissions from primary and secondary oil production. In 1981 the program was expanded to include tertiary or thermally exhanced production. There was a program hold of approximately one year while funding for the latter segment was obtained.

California is the fourth largest producer of crude oil in the United States. As such, the petroleum industry is an important contributor to the state's economy. The industry can be expected to grow in California as production of the vast heavy oil reserves is increased due to the development of improved recovery techniques and economic incentives.

SECTION 2.0

OBJECTIVES

The primary objective of this program has been to quantify the average annual hydrocarbon, NO_x, SO_x, CO and particulate emissions associated with oil recovery and gas processing for the State of California on an oil field or gas plant, county, air basin and statewide basis. California's oil producing activities are concentrated in the counties of Orange, Los Angeles, Monterey, San Luis Obispo, Santa Barbara, Venture, Kern and Fresno as well as offshore production locations in state and federal waters.

SECTION 3.0

PROGRAM APPROACH

As in any inventory program the basic approach is to locate and identify emission sources and apply suitable emission factors to compute and then categorize the emissions. Because there are so many individual sources of oil production emissions (43,000 oil wells in approximately 230 fields) it was necessary to use sampling procedures in order to develop both the number of sources and emission factors. Realize that in California there are over 1.5 million oil field valves and three million oil field fittings. Various techniques can be used to complete existing information from which emissions could be determined. This section summarizes the general approach taken by KVB.

As stated above, the primary objective of the inventory was to compile emissions of the five criteria pollutants, NO_x, SO_x, particulate, THC, and CO by oil field or gas plant, county, air basin, and state. To ensure that a proper representation of oil field characteristics and operations were incorporated in the sampling process, oil fields were grouped according to specific parameters. Representative fields from each group were then selected for inventory. The inventory procedures were further refined by inventorying specific leases at each field. The lease was the lowest level on which data were compiled.

KVB crews visited over 30 oil production sites including offshore platforms, production islands and gas plants. These sites were systematically selected as representative of various oil leases in the state. Detailed counts were made of valves, fittings, and surface equipment associated with petroleum production or gas processing. The estimated 2,500 leases in the state were segregated into ten categories. For each of the ten categories, unique emissions models or algorithms were prepared. The emissions for each respective lease in that category were then determined based on the number of wells and throughput rate for that lease. Two other category models were developed which covered the special cases of (1) gas plants, and (2) onshore treatment facilities which receive crude and gas produced by the offshore platforms.

These lease category models were constructed using the following procedure. Fugitive hydrocarbon emissions from sources including valves, fittings, sumps, pits, mechanical oil/water separators, compressors, etc. were quantified on a lease-by-lease basis using the appropriate lease algorithm along with the number of wells on that lease. These fugitive-hydrocarbon sources were inventoried at each production survey site by type (i.e., globe valve, threaded fitting, rotary seal...etc.). Using the hydrocarbon leakage rate data published by the American Petroleum Institute (API) (Ref. 1) the total emissions per hardware item category (i.e. valve, fitting sumps, etc.) was obtained. Summing the emissions from all sources in a particular hardware item category for the production sites surveyed within a lease model group and dividing by the total number of wells surveyed in that group produced an emission algorithm for each hardware item category in units of lb/day of emissions per well. These hardware item algorithms were then summed to obtain a unique model for that lease which included emissions from valves, fittings, pumps, compressors, etc. Then, to estimate the fugitive hydrocarbon emissions from a given lease, the number of wells for that lease was multiplied by that unique lease model parameter.

Tank breathing loss and working loss emissions were calculated as a function of production rate or annual throughput. Based on a model developed from a statistical sampling of lease tank capacities versus annual production rates, the tank capacity for each lease was determined. The lease tankage, in a given field was summed to find total tankage which was used to determine annual breathing loss emissions. The total field production rate was used to determine working loss emissions. These emissions were calculated from algorithms developed from the AP-42 fixed-roof tank emission equations and tankage characteristics specific to the oil fields. Separate algorithms were used for tankage with and without vapor control.

Steam generators, heater treaters, boilers, fire floods and IC engines were inventoried on a field rather than lease basis. The statistical basis for these were IC engine count; heater treater, steam generator and boiler capacity or rated heat input rate; plus incremental oil production rate resulting from fireflooding operations. Emission factors for the various emission sources were developed from (1) KVB's field testing program (conducted under this contract), (2) AP-42, and (3) KVB's tertiary oil recovery report (Ref. 2), previously prepared for ARB.

A computer program, written for this project, aggregated the emissions from each of those sources by field, county...etc. Emissions calculated by the program were expressed as metric tons/year. Each field was located by up to six Universal Transverse Mercator (UTM) coordinates.

SECTION 4.0

SUMMARY OF RESULTS

4.1 TOTAL ANNUAL EMISSIONS

The primary results obtained in this program were a quantification of NO_x, SO_x, THC, particulate, and CO emissions associated with oil production and gas processing on a field or gas plant, county, air basin and statewide basis. These emissions included those from Fresno, Kern, Orange, Los Angeles, San Luis Obispo, Monterey, Santa Barbara, and Ventura Counties and the offshore producing locations in state and federal waters. These areas include nearly all the major oil fields in the state. The total annual emissions in metric tons for each facility by county are presented in Table 1. The emissions by air basin and emission category are presented in Tables 2 through 5. The total statewide emissions associated with petroleum production based on the eight-study counties are presented in Table 6.

Aggregated in this table are emissions associated with tanks, well cellars, sumps and pits, valves, fittings, well heads, pumps, compressors, IC engines, heater treaters, steamers and boilers, mechanical oil/water separators, fireflooding, and flares. Not included, as explained below, are emissions associated with oil well drilling and steam enhanced oil recovery well vent emissions.

On the basis of these results, it can be seen that emissions from oil production are a significant portion of the total emissions from stationary sources in California. Table 7 compares the South Coast Air Basin emissions for petroleum production as estimated by this program to the Draft 1979 Stationary Source Emissions Inventory prepared by the South Coast Air Quality Management District.

4.2 DRILLING RIGS

Drilling rig emissions were calculated on a regional basis rather then a field by field basis. This approach more accurately estimates the total annual emissions and eliminates wide fluctuations which might occur in a given field from year to year due to increases or decreases in drilling activity. Further, the regional approach also accounts for "wildcatting" and other drilling which occurs outside specific oil field boundaries. The results of the analysis for the year 1979 are presented in Table 8.

Drilling in California is done by electric, gas and diesel powered rigs. In the course of drilling an oil well, a rig's power plant will vary between idle and full load depending upon depth, hardness of formation and whether the rig is drilling or performing some other operation. The approach used by KVB was to plot the fuel used per day and the days required to drill

TABLE 1. SUMMARY OF EMISSIONS FROM PETROLEUM PRODUCTION BY COUNTY AND FIELD IN CALIFORNIA, 1979

County	Field	Pollutant Emissions Metric Tons/Year				
		THC	NOx	CO	Part.	SOx
FRESNO	Burrel	12	--	--	--	--
	Burrel, Southeast	20	--	--	--	--
	Camden	3	--	--	--	--
	Cheney Ranch Gas	13	--	--	--	--
	Coalinga	3,343	1,043	3,266	426	2,887
	Coalinga, Extension	458	33	735	--	--
	Five Points	3	--	--	--	--
	Guijarral Hills	83	6	147	--	--
	Helm	238	34	765	--	--
	Jacalitos	180	33	735	--	--
	Kettleman, North Dome	239	--	--	--	--
	Kreyenhagen	20	--	--	--	--
	Pleasant Valley	10	--	--	--	--
	Raisin City	372	65	1,470	--	--
	Riverdale	218	26	588	--	--
	San Joaquin	17	--	--	--	--
	Turk Anticline	6	--	--	--	--
	Westhaven	8	--	--	--	--
	Subtotal	5,243	1,240	7,706	426	2,887
	(Gas Plant)					
	Coalinga Nose	2,464	2,646	829	2	832
	COUNTY TOTAL	7,707	3,886	8,535	428	3,719
KERN	Ant Hill	82	--	--	--	--
	Antelope Hills	173	--	--	--	--
	Antelope Hills, North	24	--	--	--	--
	Asphalto	353	26	588	--	--
	Beer Nose	13	--	--	--	--
	Belgian Anticline	485	13	2	6	41
	Bellevue	70	6	147	--	--
	Bellevue, West	14	--	--	--	--
	Belridge, North	689	125	16	57	385
	Belridge, South	5,252	1,896	4,319	932	5,642
	Blackwell Corner	40	--	--	--	--
	Buena Vista	2,665	138	2,211	18	124
	Cal Canal	35	--	--	--	--
	Calders Corner	3	--	--	--	--
	Canal	63	9	206	--	--
	Canfield Ranch	386	39	883	--	--
	Carneros Creek	12	--	--	--	--
	Chico-Martinez	26	--	--	--	--
	Cienega Canyon	5	--	--	--	--
	Coles Levee, North	637	105	2,353	--	--
	Coles Levee, South	46	--	--	--	--
	Commanche Point	66	--	--	--	--
	Cymric	2,944	342	3,730	87	592
	Devils Den	225	--	--	--	--
	Edison	2,570	269	4,421	33	223
	Edison, Northeast	44	37	[illegible]	17	115
	Elk Hills	2,446	1,049	23,528	--	1
	English Colony	10	--	--	--	--
KERN (Cont)	Fruitvale	1,324	148	2,066	26	174
	Goosloo	30	--	--	--	--
	Greeley	179	13	295	--	--
	Jasmin	156	--	--	--	--
	Jasmin, West	9	--	--	--	--
	Jerry Slough	3	--	--	--	--
	Kern Bluff	303	97	13	44	298
	Kern Front	2,244	854	1,458	383	2,594
	Kern River	4,409	13,594	3,549	6,189	41,925
	Lakeside	3	--	--	--	--
	Los Lobos	5	--	--	--	--
	Lost Hills	3,667	469	178	225	1,435
	Lost Hills, Northwest	5	--	--	--	--
	McDonald Anticline	308	--	--	--	--
	McKittrick	1,670	733	95	334	2,265
	Midway-Sunset*	16,063	4,745	17,891	2,062	13,856
	Mount Poso	1,360	304	420	137	927
	Mountain View	1,013	131	2,941	--	--
	Paloma	179	--	--	--	--
	Pioneer	10	--	--	--	--
	Pleito	81	--	--	--	--
	Poso Creek	1,272	230	410	103	698
	Railway Gap	96	88	11	40	271
	Rio Bravo	145	1	58	--	--
	Rio Viejo	36	--	--	--	--
	Rosedale	47	--	--	--	--
	Rosedale Ranch	210	33	735	--	--
	Round Mountain	795	--	--	--	--
	San Emidio Nose	40	--	--	--	--
	Semitropic	114	--	--	--	--
	Seventh Standard	9	--	--	--	--
	Strand	199	41	911	--	--
	Tejon	454	79	1,472	6	41
	Tejon Hills	310	--	--	--	--
	Tejon North	355	33	735	--	--
	Temblor Hills	3	--	--	--	--
	Temblor Ranch	10	--	--	--	--
	Ten Section	620	11	1,027	--	--
	Tule Elk	8	--	--	--	--
	Union Avenue	16	3	59	--	--
	Valpredo	3	--	--	--	--
	Welcome Valley	6	--	--	--	--
	Wheeler Ridge	449	83	1,473	8	57
	White Wolf	43	1	58	--	--
	Yowlumne	297	12	265	--	--
	Subtotal	57,936	25,757	78,529	10,707	71,665
	(Gas Plants)					
	Belridge	1,889	2,028	635	1	638
	Buena Vista	369	397	124	--	125
	Cajon	205	221	69	--	69
	Cymric	205	221	69	--	69
	Lost Hills	205	221	69	--	69
	McKittrick	738	793	248	--	250
	Midway-Sunset	1,395	1,498	469	1	471

*Fields in more than one county.

NOTE: Dash represents no emissions or less than one metric ton/year.

TABLE 1. (CONTINUED)

County	Field	Pollutant Emissions Metric Tons/Year THC	NOx	CO	Part.	SOx
KERN (Cont)	(Gas Plants, cont)	--	--	--	--	--
	North Coles Levee	1,190	1,277	400	1	402
	Rio Bravo	533	572	179	--	180
	South Coles Levee	3,203	3,439	1,077	2	1,082
	Subtotal	9,932	10,667	3,339	5	3,355
	COUNTY TOTAL	67,868	36,424	81,868	10,712	75,020
LOS ANGELES	Aliso Canyon	271	13	295	--	--
	Alondra	7	--	--	--	--
	Bandini	127	26	588	--	--
	Beverly Hills	497	2	234	--	--
	Brea-Olinda*	238	1	--	3	1
	Canton Creek	5	--	--	--	--
	Cascade	47	--	--	--	--
	Castaic Hills	129	26	588	--	--
	Castaic Junction	78	--	--	--	--
	Cheviot Hills	97	--	--	--	--
	Coyote, West*	24	--	--	--	--
	Del Valle	284	12	500	--	--
	Dominguez	514	144	3,236	--	--
	El Segundo	60	1	89	--	--
	Hasley Canyon	32	--	--	--	--
	Honor Rancho	69	5	117	--	--
	Howard Townsite	128	22	501	--	--
	Hyperion	4	--	--	--	--
	Inglewood	1,219	--	--	--	--
	Las Cienegas	51	--	--	--	--
	Las Llajas	13	3	59	--	--
	Lawndale	8	--	--	--	--
	Long Beach	1,511	130	2,941	--	--
	Long Beach Airport	76	4	89	--	--
	Los Angeles, Downtown	16	--	--	--	--
	Los Angeles, East	63	18	412	--	--
	Lyon Canyon	15	--	--	--	--
	Montebello	444	--	--	--	--
	Newgate	5	--	--	--	--
	Newhall	245	--	--	--	--
	Newhall-Potrero	393	33	735	--	--
	Oak Canyon	108	10	234	--	--
	Placerita	533	16	1	1	--
	Playa del Rey	39	--	--	--	--
	Potrero	84	--	--	--	--
	Ramona*	226	26	588	--	--
	Rosecrans	400	46	1,030	--	--
	Rosecrans, East	13	3	59	--	--
	Rosecrans, South	108	20	471	--	--
	Salt Lake	169	--	--	--	--
	Salt Lake, South	51	--	--	--	--
	San Vicente	17	--	--	--	--
	Sansinena	476	--	--	--	--
	Santa Fe Springs	695	92	2,058	--	--
	Saugus	8	--	--	--	--
	Sawtelle	74	1	115	--	--
	Seal Beach*	374	42	941	--	--
LOS ANGELES (Cont)	Tapia	63	--	--	--	--
	Torrance	1,285	30	940	--	--
	Union Station	36	--	--	--	--
	Venice Beach	16	--	--	--	--
	Wayside Canyon	14	--	--	--	--
	Whittier	616	--	--	--	--
	Wilmington	3,183	168	4,409	1	--
	Subtotal	15,258	894	21,230	5	1
	(Gas Plants)					
	Dominguez	163	176	55	--	55
	Inglewood	163	176	55	--	55
	Lomita	287	309	97	--	97
	Newhall	1,520	1,632	511	1	513
	Santa Fe Springs	82	88	27	--	28
	Torrance	42	45	14	--	14
	Subtotal	2,257	2,426	759	1	762
	COUNTY TOTAL	17,515	3,320	21,989	6	763
MONTEREY	King City	102	--	--	--	--
	Lynch Canyon	5	--	--	--	--
	McCool Ranch	5	--	--	--	--
	Monroe Swell	15	--	--	--	--
	Paris Valley	10	--	--	--	--
	Quinado Canyon	5	--	--	--	--
	San Ardo	1,534	1,835	239	874	5,632
	COUNTY TOTAL	1,676	1,835	239	874	5,632
ORANGE	Brea-Olinda*	1,786	55	65	27	166
	Coyote, East	496	4	352	--	--
	Coyote, West*	867	20	1,905	--	--
	Esperanza	56	--	--	--	--
	Huntington Beach	4,059	474	10,500	6	42
	Kraemer	19	--	--	--	--
	Newport, West	451	23	3	35	47
	Olive	32	--	--	--	--
	Richfield	677	--	--	--	--
	Seal Beach*	253	43	970	--	--
	Sunset Beach	20	--	--	--	--
	Yorba Linda	707	26	3	12	83
	Subtotal	9,423	645	13,798	80	338
	(Gas Plants)					
	Coyote, East	369	396	125	--	123
	Coyote, West	81	88	27	--	28
	Huntington Beach	411	442	140	--	139
	Subtotal	861	926	292	0	290
	(Offshore Facility)					
	Belmont	92	--	--	--	--
	COUNTY TOTAL	10,376	1,571	14,090	80	628

*Fields in more than one county.

NOTE: Dash represents no emissions or less than one metric ton/year.

TABLE 1. (CONTINUED)

County	Field	THC	NOx	CO	Part.	SOx
		Pollutant Emissions Metric Tons/Year				
SAN LUIS OBISPO	Arroyo Grande	262	223	29	102	688
	Guadalupe*	651	537	3,755	169	1,148
	Midway-Sunset*	146	19	296	17	3
	Morales Canyon	5	--	--	--	--
	Russell Ranch*	176	35	793	--	--
	Taylor Canyon	8	--	--	--	--
	COUNTY TOTAL	1,248	814	4,873	288	1,839
SANTA BARBARA	Barham Ranch	36	7	147	--	--
	Capitan	59	--	--	--	--
	Careaga Canyon	5	--	--	--	--
	Casmalia	617	106	1,476	18	124
	Cat Canyon	3,132	272	4,538	34	230
	Cuyama, South	318	131	2,941	--	--
	Elwood	45	--	--	--	--
	Four Deer Field	39	--	--	--	--
	Guadalupe*	14	3	59	--	--
	Lompoc	396	--	--	--	--
	Orcutt	936	177	3,971	--	--
	Point Conception	25	--	--	--	--
	Russell Ranch*	103	44	1,000	--	--
	Santa Maria Valley	1,305	191	4,117	--	--
	Zaca	133	--	--	--	--
	Subtotal	7,163	931	18,249	52	354
	(Gas Plants)					
	Gaviota	245	263	82	--	83
	Santa Maria	575	617	193	--	194
	Subtotal	820	880	275		277
	(Offshore Facilities)					
	Alegria	10	--	--	--	--
	Carpenteria	176	--	--	--	--
	Dos Cuadras	50	--	--	--	--
	Elwood, South	12	--	--	--	--
	Summerland	28	--	--	--	--
	Subtotal	276				
	Carpenteria Onshore Facility	1,117	542	1,398		166
	COUNTY TOTAL	9,376	2,353	19,922	52	797
VENTURA	Bardsdale	469	--	--	--	--
	Big Mountain	23	6	117	--	--
	Canada Larga	16	--	--	--	--
	El Rio	5	--	--	--	--
	Eureka Canyon	76	--	--	--	--
	Holser	57	--	--	--	--
	Hopper Canyon	59	10	234	--	--
	Los Posas	5	--	--	--	--
	Montalvo, West	128	--	--	--	--
	Moorpark, West	11	--	--	--	--
	Oak Park	30	--	30	--	--
VENTURA (Cont)	Oakridge	16	--	--	--	--
	Ojai	638	67	1,617	--	--
	Oxnard	417	7	1	--	--
	Piru	43	--	--	--	--
	Ramona*	361	26	588	--	--
	Rincon	875	1	--	--	--
	San Miguelito	249	26	588	--	--
	Santa Clara Avenue	42	1	88	--	--
	Santa Paula	121	13	295	--	--
	Santa Susana	36	--	--	--	--
	Saticoy	139	--	--	--	--
	Sespe	1,098	98	2,206	--	--
	Shiells Canyon	190	--	--	--	--
	Simi	165	--	--	--	--
	South Mountain	1924	67	1,587	--	--
	Tapo Canyon, South	83	13	2	6	41
	Tapo Canyon, North	17	--	--	--	--
	Tapo Ridge	5	--	--	--	--
	Temescal	67	--	--	--	--
	Timber Canyon	97	--	--	--	--
	Torrey Canyon	219	3	294	--	--
	Ventura	1939	98	2,206	--	--
	West Mountain	106	--	30	--	--
	Subtotal	9,725	436	9,883	6	41
	(Gas Plants)					
	Montalvo, West	245	263	82	--	83
	Ojai	163	176	55	--	55
	Santa Clara	699	750	235	--	236
	Ventura	493	530	166	--	166
	Subtotal	1,600	1,719	538		540
	Rincon Onshore Facility	593	14	1,233		
	COUNTY TOTAL	11,918	2,169	11,654	6	581

*Fields in more than one county.

NOTE: Dash represents no emissions or less than one metric ton/year.

TABLE 2. 1979 TOTAL EMISSIONS FROM PETROLEUM PRODUCTION IN NORTH CENTRAL AIR BASIN

PROCESS NAME	EMISSIONS BY POLLUTANT IN METRIC TONS PER YEAR THC	NO_x	CO	Part.	SO_x
Tanks Breathing Loss	274.9	0.0	0.0	0.0	0.0
Tanks Working Loss	119.2	0.0	0.0	0.0	0.0
Well Cellars	5.0	0.0	0.0	0.0	0.0
Sumps and Pits	887.9	0.0	0.0	0.0	0.0
Valves	141.0	0.0	0.0	0.0	0.0
Fittings	77.0	0.0	0.0	0.0	0.0
Well Heads	0.8	0.0	0.0	0.0	0.0
Pumps	0.5	0.0	0.0	0.0	0.0
Steamer/Boiler-Oil Fired	53.5	1820.8	236.1	830.1	5623.2
Fire Flood	117.1	14.5	2.6	43.8	8.7
Total	1676.9	1835.3	238.7	873.9	5631.9

TABLE 3. 1979 TOTAL EMISSIONS FROM PETROLEUM PRODUCTION IN SOUTH CENTRAL AIR BASIN

PROCESS NAME	EMISSIONS BY POLLUTANT IN METRIC TONS PER YEAR THC	NO_x	CO	Part.	SO_x
Tanks Breathing Loss	1589.1	0.0	0.0	0.0	0.0
Tanks Working Loss	164.6	0.0	0.0	0.0	0.0
Well Cellars	318.9	0.0	0.0	0.0	0.0
Sumps and Pits	2011.7	0.0	0.0	0.0	0.0
Valves	7641.6	0.0	0.0	0.0	0.0
Fittings	3247.5	0.0	0.0	0.0	0.0
Well Heads	0.4	0.0	0.0	0.0	0.0
Pumps	27.7	0.0	0.0	0.0	0.0
Compressors	460.9	0.0	0.0	0.0	0.0
IC Engines	2644.3	1429.8	32086.1	0.0	0.5
Heater Treater	1305.5	33.6	3288.3	0.0	0.0
Steamer/Boiler-Oil Fired	20.9	722.2	93.5	329.0	2230.8
Tanks Breathing Loss With Vapor Control	47.7	0.0	0.0	0.0	0.0
Tanks Working Loss With Vapor Control	76.2	0.0	0.0	0.0	0.0
Mechanical Oil/Water Separator	30.4	0.0	0.0	0.0	0.0
Fire Flood	45.3	5.6	1.0	17.0	3.4
Steamer/Boiler-Gas Fired	0.2	16.0	1.2	0.6	0.0
Heater Treater	11.1	2.8	200.8	0.0	0.0
Boiler-Gas Plant	0.4	32.4	2.8	1.6	0.0
Flare-Gas Plant	0.0	0.0	0.0	0.0	983.9
Sumps & Pits-Gas Plant	34.8	0.0	0.0	0.0	0.0
Valves-Gas Plant	1031.1	0.0	0.0	0.0	0.0
Fittings-Gas Plant	233.9	0.0	0.0	0.0	0.0
Pumps-Gas Plant	10.6	0.0	0.0	0.0	0.0
Compressor/Driver-Gas Plant	1592.0	3093.6	775.9	0.0	0.1
Total	22546.8	5336.0	36449.6	348.2	3218.7

TABLE 4. 1979 TOTAL EMISSIONS FROM PETROLEUM PRODUCTION IN SOUTH COAST AIR BASIN

PROCESS NAME	EMISSIONS BY POLLUTANT IN METRIC TONS PER YEAR THC	NO_x	CO	Part.	SO_x
Tanks Breathing Loss	1798.9	0.0	0.0	0.0	0.0
Tanks Working Loss	200.8	0.0	0.0	0.0	0.0
Well Cellars	218.7	0.0	0.0	0.0	0.0
Sumps and Pits	4164.9	0.0	0.0	0.0	0.0
Valves	9054.4	0.0	0.0	0.0	0.0
Fittings	4047.5	0.0	0.0	0.0	0.0
Well Heads	4.4	0.0	0.0	0.0	0.0
Pumps	38.9	0.0	0.0	0.0	0.0
Compressors	432.1	0.0	0.0	0.0	0.0
IC Engines	2466.9	1334.1	29938.7	0.0	0.7
Heater Treater	2014.3	52.1	5073.3	0.0	0.2
Steamer/Boiler-Oil Fired	2.8	106.7	13.7	48.4	330.4
Tanks Breathing Loss With Vapor Control	82.9	0.0	0.0	0.0	0.0
Tanks Working Loss With Vapor Control	84.0	0.0	0.0	0.0	0.0
Mechanical Oil/Water Separator	73.4	0.0	0.0	0.0	0.0
Fire Flood	92.5	11.4	1.9	34.6	6.8
Steamer/Boiler-Gas Fired	0.5	37.5	3.1	1.7	0.0
Heater Treater-Gas Plant	11.9	2.9	214.8	0.0	0.0
Boiler-Gas Plant	0.3	34.8	2.9	1.6	0.0
Flare-Gas Plant	0.0	0.0	0.0	0.0	1053.4
Sumps & Pits-Gas Plant	37.1	0.0	0.0	0.0	0.0
Valves-Gas Plant	1103.7	0.0	0.0	0.0	0.0
Fittings-Gas Plant	250.0	0.0	0.0	0.0	0.0
Pumps-Gas Plant	11.2	0.0	0.0	0.0	0.0
Compressor/Driver-Gas Plant	1704.2	3312.1	830.4	0.0	0.2
Total	27896.3	4891.6	36078.8	86.3	1391.7

TABLE 5. 1979 TOTAL EMISSIONS FROM PETROLEUM PRODUCTION IN SAN JOAQUIN AIR BASIN

PROCESS NAME	EMISSIONS BY POLLUTANT IN METRIC TONS PER YEAR				
	THC	NO_x	CO	Part.	SO_x
Tanks Breathing Loss	2350.7	0.0	0.0	0.0	0.0
Tanks Working Loss	1430.8	0.0	0.0	0.0	0.0
Well Cellars	495.8	0.0	0.0	0.0	0.0
Sumps and Pits	23807.8	0.0	0.0	0.0	0.0
Valves	12530.9	0.0	0.0	0.0	0.0
Fittings	5779.1	0.0	0.0	0.0	0.0
Well Heads	20.2	0.0	0.0	0.0	0.0
Pumps	51.2	0.0	0.0	0.0	0.0
Compressors	538.8	0.0	0.0	0.0	0.0
IC Engines	4726.7	2556.1	57351.0	0.0	1.2
Heater Treater	10223.2	264.7	25748.0	0.0	1.6
Steamer/Boiler-Oil Fired	708.6	24130.4	3128.5	10999.9	74522.3
Tanks Breathing Loss With Vapor Control	27.8	0.0	0.0	0.0	0.0
Tanks Working Loss With Vapor Control	79.0	0.0	0.0	0.0	0.0
Mechanical Oil/Water Separator	58.9	0.0	0.0	0.0	0.0
Fire Flood	353.6	44.1	7.9	132.6	26.5
Steamer/Boiler-Gas Fired	0.0	2.5	0.1	0.0	0.0
Heater Treater-Gas Plant	48.0	13.0	854.6	0.0	0.1
Boiler-Gas Plant	2.3	139.6	13.0	7.5	0.1
Flare-Gas Plant	0.0	0.0	0.0	0.0	4186.1
Sumps & Pits-Gas Plant	149.4	0.0	0.0	0.0	0.0
Valves-Gas Plant	4386.0	0.0	0.0	0.0	0.0
Fittings-Gas Plant	995.1	0.0	0.0	0.0	0.0
Pumps-Gas Plant	45.0	0.0	0.0	0.0	0.0
Compressor/Driver-Gas Plant	6772.1	13159.7	3300.8	0.0	1.5
Total	75680.5	40310.1	90403.9	11140.0	78739.4

TABLE 6. 1979 TOTAL EMISSIONS FROM PETROLEUM PRODUCTION IN CALIFORNIA

PROCESS NAME	EMISSIONS BY POLLUTANT IN METRIC TONS PER YEAR THC	NO_x	CO	Part.	SO_x
Tanks Breathing Loss	6013.6	0.0	0.0	0.0	0.0
Tanks Working Loss	1915.4	0.0	0.0	0.0	0.0
Well Cellars	1038.4	0.0	0.0	0.0	0.0
Sumps and Pits	30872.3	0.0	0.0	0.0	0.0
Valves	29367.9	0.0	0.0	0.0	0.0
Fittings	13151.1	0.0	0.0	0.0	0.0
Well Heads	25.6	0.0	0.0	0.0	0.0
Pumps	118.3	0.0	0.0	0.0	0.0
Compressors	1431.8	0.0	0.0	0.0	0.0
IC Engines	9837.9	5320.0	119375.8	0.0	2.4
Heater Treater	13543.0	350.4	34109.6	0.0	1.8
Steamer/Boiler-Oil Fired	785.8	26780.1	3471.8	12207.4	82706.7
Tanks Breathing Loss With Vapor Control	158.4	0.0	0.0	0.0	0.0
Tanks Working Loss With Vapor Control	239.2	0.0	0.0	0.0	0.0
Mechanical Oil/Water Separator	162.7	0.0	0.0	0.0	0.0
Fire Flood	608.5	75.6	13.4	228.0	45.4
Steamer/Boiler-Gas Fired	0.7	56.0	4.4	2.3	0.0
Heater Treater-Gas Plant	71.0	18.7	1270.2	0.0	0.1
Boiler-Gas Plant	3.0	206.8	18.7	10.7	0.1
Flare-Gas Plant	0.0	0.0	0.0	0.0	6223.4
Sumps & Pits-Gas Plant	221.3	0.0	0.0	0.0	0.0
Valves-Gas Plant	6520.8	0.0	0.0	0.0	0.0
Fittings-Gas Plant	1479.0	0.0	0.0	0.0	0.0
Pumps-Gas Plant	66.8	0.0	0.0	0.0	0.0
Compressor/Driver-Gas Plant	10068.3	19565.4	4907.1	0.0	1.8
Total	127800.5	52373.0	163171.0	12448.4	88981.7

TABLE 7. COMPARISON OF SOUTH COAST AIR BASIN OIL PRODUCTION EMISSIONS TO THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT DRAFT 1979 EMISSION INVENTORY

	Emissions (thousand metric tons/yr)				
	THC	CO	NO_x	SO_x	Particulates
Total Stationary Sources[1]	783	198	146	70	175
Petroleum Production[2]	28	36	4.9	1.4	0.1
Petroleum Production Percentage	3.6	18.2	3.4	2.0	0.06

[1]Source: Annual Report For 1980 on The South Coast Air Quality Management Plan, South Coast Air Quality Management District, September, 1981.

[2]Source: South Coast Air Basin emissions estimated by this program.

TABLE 8. POLLUTANT EMISSIONS FROM DRILLING RIGS IN 1979

		(Metric Tons/Yr)				
		NO_x	SO_x	CO	THC	Particulates
San Joaquin Valley						
	Diesel	331	22	72	26	24
	Gas	59	(a)	7	24	NA[b]
Coastal Area						
	Diesel	111	7	24	9	8
	Gas	38	(a)	5	16	NA[b]
Los Angeles Basin						
	Diesel	53	4	12	4	4
	Gas	8	(a)	1	3	NA[b]
		600	33	121	82	36

Emission Factor Source: AP-42 Tables 3.3.2-1 and 3.3.3-1

[a] Less than one metric ton

[b] Emission factor not available in AP-42

for various depth wells in the San Joaquin Valley, Coastal Area, and the Los Angeles Basin. This integrated the many cycle fluctuations involved in drilling a well.

To calculate emissions it was necessary to first determine the average depth well drilled in each region. From that the total amount of equivalent diesel fuel required could be found from the graphs of fuel per day and time required versus depth. This was apportioned into diesel fuel and natural gas using the horsepower ratios of the rigs located in each region. A correction was also made for electrically driven rigs. The emissions were then calculated using AP-42 emission factors.

4.3 TERTIARY OIL RECOVERY WELL VENTS

Steam enhanced oil recovery well vents have been found to be significant sources of hydrocarbon emissions. These emissions can be controlled through the use of centralized vapor recovery systems, however, in many locations there is no control system used. Using recently published data, prepared by Radian for EPA (Ref. 3), KVB has analyzed the volatile organic compound (VOC) emissions resulting from these well vents on a field-by-field basis. These emissions are reported separately and were not included in the computer program as VOC's were not compatible with the computer program and the emissions data became available after the computer program had been written. The emissions are summarized in Table 9.

4.4 IC ENGINE EMISSION FACTORS

During the test phase of this program, KVB found wide variations in engine operating conditions and emission levels of CO, NO_x, and THC. The findings suggest that there is no single correlation between the emission levels and any specific operating parameter. However, using the results from testing 22 IC engines, a set of overall emission factors was developed. These are presented in Table 10.

TABLE 9. WELL VENT VOC EMISSIONS FROM STEAM ENHANCED CRUDE OIL PRODUCTION WELLS

County	Field	VOC Emissions Metric Tons/yr
Fresno	Coalinga	6,390
Monterey	San Ardo	36
Santa Barbara	Cat Canyon	0
	Santa Maria Valley	39
	Casmalia	0
San Luis Obispo	Guadalupe	0
	Arroyo Grande	0
Orange	Yorba Linda	9,110
	Huntington Beach	46
	Brea-Olinda	1
	Newport, West	2
Ventura	Shiells Canyon	69
	Oxnard	1
	Tapo Canyon, South	1
Kern	Belridge, South	56,500
	Cymric	317
	Edison	333
	Fruitvale	2
	Kern Bluff	18
	Kern Front	1,470
	Kern Front/Poso	15
	Kern River	24,700
	Lost Hills	285
	McKittrick	2,250
	Midway Sunset	23,300
	Mount Poso	9,380
	Poso Creek	54
	Temblor Valley	2
	Belgian Anticline	1
	Buena Vista	1
	Railroad Gap	1
	Tejon	1
	Wheeler Ridge	1
	Edison, Northeast	4
Los Angeles	Placerita	1
	Wilmington	1

TABLE 10. EMISSION FACTORS FOR GAS-FIRED INTERNAL COMBUSTION ENGINES FOUND IN CALIFORNIA OIL FIELDS*

	Nitrogen Oxides (as NO_2)		Carbon Monoxide		Hydrocarbons as CH_4		Hydrocarbons as TOC		Sulfur Dioxide†
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	Estimated
Internal Combustion Engines									
≤ 100 HP									
ppm, dry @ 15% O_2	180	36-389	3100	148-8800	450	3.0-1720	1400	218-2200	0.096
lb/hr§	0.35	0.051-0.81	3.3	0.19-9.3	0.32	0.0020-1.2	0.51	0.11-1.1	0.00024
grams/HP-hr	6.6	0.88-18	74	4.2-230	7.9	0.047-28	13	1.7-27	0.0051
lbs/MMBtu	0.71	0.20-1.6	9.2	0.41-27	0.70	0.0042-2.2	1.1	0.23-2.1	0.00053
lbs/M bbl. gross production	240	16-730	3100	180-17,000	39	1.9-110	260	110-520	0.18
ng/J	310	86-690	4000	180-11,600	300	1.8-930	470	100-1000	0.23
100-300 HP									
ppm, dry @ 15% O_2	140	12-628	8800	136-20,000	660	0.62-3300	1300	413-4500	0.11
lb/hr§	0.28	0.026-0.81	15	0.31-30	0.39	0.00052-1.9	0.67	0.37-1.9	0.00040
grams/HP-hr	4.0	0.28-19	150	14-270	6.1	0.0057-23	8.8	2.3-24	0.0040
lbs/MMBtu	0.51	0.042-2.2	18	0.32-40	0.79	0.00064-3.9	1.1	0.34-4.0	0.00054
lbs/M bbl. gross production	57	2.6-160	4000	79-17,000	29	0.43-66	130	20-370	0.088
ng/J	220	18-950	7700	140-17,200	340	0.28-1700	470	150-1700	0.23
Weighted Composite ≤100 HP / 100-300 HP									
ppm, dry @ 15% O_2	170	12-628	5200	136-20,000	560	0.62-3300	1300	218-4500	0.10
lb/hr§	0.32	0.026-0.81	8.0	0.19-30	0.36	0.00052-1.9	0.60	0.11-1.9	0.00030
grams/HP-hr	5.6	0.28-19	102	4.2-270	6.9	0.0057-28	11	1.7-27	0.0047
lbs/MM Btu	0.64	0.042-2.2	13	0.32-40	0.75	0.00064-3.9	1.1	0.23-4.0	0.0053
lbs/M bbl. gross production	170	2.6-730	3400	79-17,000	33	0.43-110	190	20-520	0.14
ng/J	270	18-950	5500	140-17,200	320	0.28-1700	470	100-1700	0.23

*Results based on tests run on 22 gas-fired internal combustion engines; eight have HP ratings >100 HP, and 14 have HP ratings ≤100 HP. Average engine load measured was 37%, HP 88. Tests occurred at three different oil fields in the South Coast Air Basin. Fuel used was either natural gas or processed field gas.

†Based on a typical natural gas sulfur content of 2000 grains per 10^6 scf as reported in AP-42, Section 1.4.1.

§Even though lbs/hr is an emission rate and not an emission factor, it is provided here for convenience.

4.5 FIELD HEATER EMISSION FACTORS

Tests conducted on eight oil field heaters and heater treaters indicate that NO_x emission levels are low. The test results also showed that the levels of CO, THC and carbon (Bacharach Smoke Spot Number) could be quite high due to either a combustion air excess or deficiency resulting from poor tuning or partially plugged air inlets. Composite emission factors for the eight heaters are presented in Table 11.

SECTION 5.0

CONCLUSIONS

This program has resulted in a comprehensive emission inventory for the oil production industry in California for the year 1979. In addition, a computerized emissions data base has been compiled which with the developed methodology can be updated annually.

SECTION 6.0

RECOMMENDATIONS

For the most part, housekeeping at the sites visited was relatively good and at several sites it was impressive. There were several sites which were in need of cleanup and valve and fitting maintenance. Oil leaks and spills and poorly maintained piping and equipment contribute significantly to fugitive hydrocarbon emissions. Valve and fitting maintenance requirements developed jointly by the oil industry and the air regulatory agencies and the sump and pit reduction program conducted by the Division of Oil and Gas should significantly reduce fugitive emissions. Additionally, general housekeeping and maintenance of equipment such as tanks needs to be encouraged. Well vents currenty release large amounts of VOC emissions. These quantities will increase as the use of thermally enhanced production increases. These emissions should be controlled both from an air quality and a product loss standpoint.

TABLE 11. EMISSION FACTORS FOR GAS-FIRED OIL-FIELD-TYPE HEATERS AND HEATER-TREATERS FOUND IN CALIFORNIA OIL FIELDS

	Nitrogen Oxides (as NO_2)		Carbon Monoxide		Hydrocarbons as CH_4		Hydrocarbons as TOC		Sulfur Dioxide††
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range	Estimated
Heater-Treater* Direct Fired 3-5 MMBtu/hr * burner size									
ppm, dry @ 3% O_2	43	21-77	2200	47-8700	864	neg.-3900	1070	1.70-6300	neg.
ng/J	24	11.6-45	760	17.2-23,000	125	neg.-700	150	0.25-900	0.26
lbs/MMBtu**	0.056	0.027-0.104	1.76	0.040-7.3	0.29	neg.-1.63	0.35	0.00057-2.1	0.0006
Heater-Treater† Pilot Light Only 3-5 MMBtu/hr * burner size									
ppm, dry @ 3% O_2	88	75-107	37,000	120-80,000	18,600	1250-39,000	37,000	1230-76,000	neg.
ng/J	41	17.2-65	5600	45-11,200	1680	260-3100	2400	189-4600	0.26
lbs/MMBtu	0.096	0.04-0.152	13	0.104-26	3.9	0.60-7.2	5.5	0.44-10.6	0.0006
Small Heaters - Indirect Fired§ 500,000 Btu/hr size Stack Gas Composition @ ~80% F.R.									
ppm, dry @ 3% O_2	52	29-77	12,400	60,000-77	59	0.5-107	79	4.7-132	neg.
ng/J	26	8.6-41	2400	25-11,200	9.0	0.099-19.4	9.0	0.65-18.1	0.26
lbs/MMBtu	0.060	0.020-0.096	5.5	0.058-26	0.021	0.00023-0.045	0.021	0.00151-0.042	0.0006
Small Heaters - Direct Fired# 500,000 Btu/hr size "Propane Fuel" Stack Gas Composition @ ~60% F.R.									
ppm, dry @ 3% O_2	47		290		62		1130		neg.
ng/J	32		12.0		14.2		198		0.26
lbs/MMBtu	0.074		0.028		0.033		0.46		0.0006

*Results indicate average emission factors developed from the testing of two 6-MMBtu/hr total, one 10-MMBtu/hr total, and one 8-MMBtu/hr total dual burner/firetube horizontal crude oil (oil-water emulsion) heaters. Fourteen tests on 6 burners over a firing rate range of 20% to 80% of capacity were performed. Fuel was either processed field or natural gas.

†Pilot light tests were performed on each burner of a dual burner heater.

§Results indicate average emission factors developed from the testing of two 500,000-Btu/hr single burner/firetube horizontal crude oil heater-treater and one 348,000 Btu/hr single burner/firetube, glycol reboiler. Five tests at approximately 40 to 80% load were performed. Fuel was processed field gas.

#Results based on the data obtained from one test performed at approximately 50% load. Heater is rated at 500,000 Btu/hr, fired on LPG, and of a single burner.

**Based on a HHV of approximately 1,000 Btu/scf.

††Based on a typical natural gas sulfur content of 2,000 grains per 10^6 scf as reported in AP-42, Section 1.4.1.

There is a lack of comprehensive test derived emission factors for valves, fittings and other components associated with heavy oil production. Heavy oil production is growing in California due to improved recovery technology and a changing economic climate. Hence, an emissions testing program similar to that conducted by Rockwell for API should be performed to establish emissions data for equipment associated with heavy oil production.

Shortcuts were used in this program to estimate emissions from tanks and sumps because data and methodologies required to perform more specific estimates of these emissions are not available at this time. While tanks are a significant source of hydrocarbon emissions, adequate estimating methods have not been developed so that emissions can be accurately assessed for even a single tank. This is considered a major research area which needs to be pursued by both regulatory agencies and industry.

It is recommended that the methodology and data base developed during this program be adopted as a foundation for future work.

SECTION 7.0

VALUE TO ARB'S RELEVANT REGULATORY PROGRAM

Data developed during the program in addition to upgrading the State's emission inventory data base also provides the inventory information necessary to revise and upgrade implementation strategies for the study counties, air basins, and the entire State. Emissions information from this program is available by pollutant and emission source category on a field or gas plant, county, air basin, and statewide basis. In addition, emissions associated with well vents and drilling rigs, which were not computerized, are presented on a field or regional basis.

Emissions information generated by this program for IC engines and drilling rigs provide pertinent input to the development and modification of emission control rules. Model rules for oil field valves and fittings and well vents have been prepared and are in various stages of implementation by the cognizant APCD's. The information developed by this project can be used to update the information base used to develop these rules.

SECTION 8.0

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1. Eaton, W. S. et al., "Fugitive Hydrocarbon Emissions From Petroleum Production Operations," American Petroleum Institute, Rockwell International, March, 1980.

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3. Harris, G. E. et al., "Assessment of VOC Emissions From Well Vents Associated With Thermally Enhanced Oil Recovery," EPA 90919-81-003, Radian Corporation, September, 1981.

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